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SELECTED ARTICLE

The Manufacture of Humus.

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It has been the lot of the present writer during the last few years, and with greater emphasis, perhaps, during the last few months, to draw attention to the importance of humus in the agricultural cycle. If, in so doing, he may appear to have strayed from the relatively restricted field of sugarcane cultivaion into the wider field of general agriculture, apology for such errantry will hardly be needed. The reasons are two; in the first place, the problem of the maintenance of soil fertility here involved is itself a general one, common to all crops; in the second, the tendency, if there be such in the sugar industry, is away from the humus and in the direction of a growing use of artificials. It has been necessary, therefore, to derive examples mainly from the experience obtained in the cultivation of other crops.

In these references there has, perhaps, been too great an acceptance of the fact of the existence of a substance termed humus and too little attention paid to what humus is and how it is prepared. That omission it is here proposed to remedy in as far as so complex a subject can be dealt with adequate brevity.

Humus, then, is not a chemical entity capable of being described and defined in a chemical formula showing so many atoms of the different elements within a characteristic molecule. It is an aggregate of different chemical compounds varying widely from sample to sample, but an aggregate of which all the samples having these points in common; a common mode of origin and certain common physical and chemical properties. The residues of living organisms, in the process of decomposition, pass through a series of natural changes which result, in the production of a relatively stable body, and it is to this body that the term humus is applied. A halt is thus called in the passage of these residues from the highly complex organic substances of the body immediately after death to the simple inorganic substances, water, carbon dioxide, nitrogen and nitrogenous salts and so on, which form the ultimate products of decomposition. It is this natural halt which plays such a vital role in the maintenance of fertility. The more important properties characteristic of this relatively stable product are, on the chemical side, and acidity which cause it to react with the mineral elements of the soil and which is responsible for the liberation of potential plant food, and a carbon nitrogen ratio of approximately 10:1. On the physical side, humus has a high retentive capacity for moisture, acts as a cement causing the smaller soil particles to form aggregates and thus aids the movement of both water and air in the soil. But it is on the biological side that its properties may be found to have the most important effect through the mycorrhizal association which has only recently been recognized as of general occurence.

From the above description of the nature of humus it follows that, since all living organisms ultimately die, the source of humus is as varied as organic nature itself. Herein lies the first difficulty in offering a concise series of instructions on the lines of Mrs. Beeton for the preparation of humus; the raw material ranges from the highly nitrogenous residues of the animal carcase to plant residues consisting of almost pure carbohydrate, cellulose and lignin. A second difficulty lies in the fact the conversion to humus is a biological reaction, the work fungi and bacteria. These, being themselves organisms, require for their vigorous growth and action that, the conditions shall lie within certain broad limits particularly in regard to humidity, temperature, air supply and acidity of matrix. Further the process of preparation consists of a series of steppings-down, from one stage in the descending scale of organic complexity to a still lower stage, and each step is broadly speaking the work of some specific organism each with its own specific optimum environment to a greater or less, and in some cases greater than less extent differing from the optimum of the remaining organisms. In this respect the art of preparation consists very largely in bringing the natural environmental conditions into line with the optimum for the particular stage of the preparatory process. These difficulties may impart an ambiguity to any description of the method of manufacture which may further induce a condition similar to that of the centipede on being asked by the toad which leg moved after which. The process is not, however, so full of obstacles as that implies; all process involving fermentation are "tricky" and incapable of exact definition. That has not prevented them from being adopted on a large scale, and they form, in fact, the foundation of many large industries, such as brewing, the preparation of cacao, and the curing of tobacco. Here, as in these other cases, practice is far better than precept.

First, then as regards the raw materials; the bulk of these in an agricultural setting consists of plant residues which for the most part are composed of carbohydrates of varying resistance to the action of the attacking organisms. These like all other organisms, require a certain supply of the essential plant foods. and in the case of the more resistent tissues there is usually a deficiency of nitrogen. To make up for this deficiency some nitrogenous substance should be added to give a carbon nitrogen ratio of approximately 33:1. Success will also depend on the mechancial state of the material. Woody tissues are protected by bark, which requires to be broken down so that the organisms of destruction may have ready access. Such woody material may be broken down on the farm roads where an adequate traffic of farm vehicles occurs.

The farm also supplies suitable nitrogenous material in the form of urine and the droppings of animals. The advantage of the use of these rests not only in their availability on most farms but on the fact that such natural products are found to contain a not readily definable something which gives to them a superiority over nitrogenous materials of inorganic origin. It is a something which acts apparently through the mycorrhizal association above referred to, for, apart from the obvious increased vigour and freedom from disease which characterizes plants grown on a natural humus, a study of the root system shows a strong development of mycorrhiza. Humus, it is true, whatever its origin, possesses a certain value as a supplier of plant food calculable in terms of N, P and K; but the value derived from this at present illdefined something transcends these more readily determined values. Chemical analysis, in fact fails as a yard measure of this latter value, and actual use may not improbably reverse the verdict of the laboratory. Until the nature of these elusive constituents of the animal residues is better understood, such residues will form a necessary raw material of an effective and sound system of agriculture.

With these two raw materials available it is now necessary to consider the conditions required if fermentation of the combined mass is to proceed along the lines which will yield the maximum of the desired product. As the fermentation proceeds, the mixture soon becomes acid, a condition inimical to the action of the micro-organisms it is desired to render most active. This acidity must be neutralized. Wood ashes, in that they supply additional potassium are very suitable for this purpose; but if these are not available calcium in the form of powdered chalk or limestone (but not quick-lime, which is too fierce) serves the purpose well and these bodies may be diluted with earth.

With these three materials to build up the matrix all the essentials for the preparation of humus are present. It now remains so to handle the mixture that the fermentative process proceeds along the lines which will result in the maximum yield of high quality product. For this purpose not only must the three constituents be sufficiently mixed for a uniform growth of the organisms concerned, but the environment must be adopted to suit their particular needs. Of the major factors of the environment, temperature may be omitted from consideration. As is well known a very considerable heat is developed in the course of the fermentative activity and this can be left to look after itself. What has to be regulated is the supply of air and moisture. The latter is required during the whole of the period of production: and abundant supply of air (the natural source of oxygen) is required only during the early stages. The reason for this is that the organisms responsible for these early stages, the decomposition of the more resistant carbohydrates, cellulose and lignin, are aerobic (operate only in the presence of ample supplies of oxygen). It is in these early stages that control is most difficult for a balance has to be struck between the amount of water and air occupying the interstitial spaces of the mass. The ideal that should be aimed at is a condition similar to that of a pressed-out sponge. In practice the tendency is in the direction of an excessive amount of water.

The need for an adequate air supply raises another point. The action of the organisms results in an absorption of the oxygen and the evolution of carbon dioxide. Unless, therefore, matters are so arranged that a sufficiently rapid interchange of gases can take place with more oxygen replacing the carbon dioxide as fast as this is formed the activity of the organisms will be slowed down. In practice it is found that adequate percolation of air into such a matrix as has been indicated proceeds only to a depth of some 18 to 24 inches.

One further point must be attended to. In whatever form of heap the matrix may be built, uniform conditions cannot be maintained throughout; the outer layers being more exposed to the air, will be subjected to more variable conditions of humidity, air supply and temperature. This has to be adjusted by intermittent turning of the heap so that the exposed material becomes buried.

The preliminary fermentation is primarily the decomposition of the non-nitrogenous carbohydrate residues and is mainly the function of aerobic fungi, for the activity of which the deficiency of nitrogen is made good by the addition of the nitrogenous substances. The decomposition of nirogenous residues is the work of anaerobic bacteria for which special measures for the aeration of the mass are not necessary.

These are the main principles underlying the successful production of compost; they must guide the practical steps, and the Indore process, now so widely adopted, is based on them and takes into consideration also the economic considerations which are of almost equal importance. In this the heap is conveniently 30 ft. long by 14 ft. wide, with the material piled to a depth of 3 ft. The pit is divided into six sections of which the second from one end is first charged, the end section being reserved for turning. The vegetable wastes are laid across the section to a depth of 6 in. and on this a layer of 2 in. of animal wastes, on which is sprinkled a mixture of urine-earth and wood ashes as a thin layer. The process is repeated till the maximum depth is reached. If the depth is greater than 2 ft. and it may be as great as 5 ft. vents must be made (conveniently done by working a crow-bar), say three to a section. The third and subsequent sections are then built in like manner. The amount of water to be sprinkled on each layer is at once the most important and difficult of the operations concerned as it will depend on the nature of the material; experience is here the best guide. Later regulation of the water supply, depending as it does on the climatic conditions, is also a matter best learned from experience. A decision is here required whether the material should be heaped or pitted and after construction, whether additional watering should be given. If correctly charged the heap will show active fungus growth in three days, and in a few days the depth will decrease from 5 ft to 3 ft.

A first turn should be made after two to three weeks, and again, after some five weeks, in the reverse direction when the aerobic stage will be approximately complete. Opportunity can be taken at each of these to regulate the humidity of the heap. A guide to the efficiency of the process is given by the temperature, which should quickly reach approximately 150°F. and fall to some 85°F. after 90 days, with intermediate rises after the turn.

The first stage, which continues up to and shortly succeeding the second turn, is the preliminary aerobic stage, and it is followed by the anaerobic stage in which the active organisms are bacteria. It is during this stage that fixation of atmospheric nitrogen takes place, and the gain of nitrogen may be considerable, for if the process is efficiently conducted there is little loss of original nitrogen in the heap that is absorbed into the body of the agents of decomposition.

After some 90 days the process slows down and the relatively stable condition of the material, to which the name humus is applied, is reached. It is now ready for the land. But complete stability is never reached. Oxidation continues, nitrification will set in, and the nitrates formed may be lost by leaching, or if carelessly stored, de-nitrification may lead to the loss of the nitrogen which so many pains have been taken to secure. Immediate application to the land is the best safeguard against such losses; if this be impossible, it should be kept under cover and turned from time to time. It is an asset which it will pay to conserve.

It is a curious fact that while some of the tropical agricultural industries notably tea and sisal, are increasingly turning their attention to the preparation and use of compost, the reverse process is taking place in the sugar industry. In those countries the West Indies and Mauritius where a long established procedure based on pen manure existed, this material is giving way to the employment of artificials. The explanation lies largely in the economic sphere; the development of the tractor has rendered the head of cattle previously kept uneconomic when considered merely as a source of power. In those newer areas Cuba, Hawaii and so on, a virgin fertility has been fortified by artificials from the commencement. It may well be asked whether a stable industry based on what is, in practice a mono-culture, can be possible in the case of sugarcane alone among crops, if the precepts of nature are so lightly regarded.

The main factors which militate against a return to organic manures are the intractability of the major residues of the crop, cane trash and bagasse, particularly the former since a large proportion of the latter is consumed as fuel, and the supposedly inadequate supply of nitrogenous wastes consequent on the reduction of the stock carried. The problem of how these wastes can be economically converted into compost has yet to be seriously tackled. The general lines are clear. It is a general experience that mixed vegetable residues are more readily decomposed than a uniform residue such as trash and it may be found economic to grow a green crop for the purpose of admixture. The other factory wastes, filter press cakes and molasses, with distillery wastes will also help in this direction as well as in supplying a mass of readily decomposable material. The nitrogenous activator if an adequate supply cannot be secured from the stock kept might well be looked for in any suitably installed sanitary system for the labour lines which are usually a feature of sugar estates. The Indore process can be readily adapted for the handling of habitation wastes under hygienic conditions. A preliminary attack on the problem has been made in South Africa by Dymond, who has shown that trash requires to be weathered a little before composting, and by Tambe and Wad in India.

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ABSTRACT

Composts and Soil Fertility C. N. Acharya, *Indian Farming* : 1 (1940, 66–68). The importance of maintaining a satisfactory level of organic matter in the soil is now generally accepted by scientists and farmers alike. The maintenance of a high level of organic matter is far more difficult in the soil of the tropical and sub-tropical regions than in that of the temperate zones. Hence, if the fertility of the tropical or sub-tropical soil is to be maintained, the application of bulky organic manures almost every year becomes quite necessary. Farm yard manure, one of the most important organic manures, is of course in largest use in this country. While the average supply of farm yard manure is about a ton per acre, the average demand is about 5 to 10 tons per acre of land under cultivation. To make up the above deficiency, composts come in quite handy as a suitable and efficient substitute. The Chinese have been adepts in the method of composting since very ancient times. There is need to copy the Chinese example, and to utilize all our resources, if the productivity of our land is to be maintained, if not improved, in view of the ever-increasing population in our country. A great many methods have been recently suggested for composting waste organic materials. The 'Adco' process developed at Rothamsted, the Indore process developed by Howard and Wad and its subsequent modifications, the Madras method worked out at Coimbatore, the Activated Compost process evolved by Dr. G. J. Fowler, the Hot Fermentation process worked out at the Indian Institute of Science, Bangalore, are some of the most important. The essential features more or less common to all the above are the following:— (1) The basic material for composting is the bulky organic refuse, e. g. leaves, weeds, stubbles, stalks, husks, etc. (2) A suitable starter is added—organic nitrogenous substances, such as night-soil, urine, sewage, activated sludge, or inorganic nitrogenous compounds such as Adco, ammonium sulphate, sodium nitrate, calcium cyanamide, etc, which serve to promote the rapid development of the necessary micro-organisms, which effect the decomposition. The amount of the starter required for decomposition depends on the amount of nitrogen initially present in the refuse. The addition of phosphorus compounds to the " starter " in the form of rock phosphate, basic slag, bone meal or super phosphate, help to improve the quality of the manure though it does not ordinarily increase the rate of decomposition. Another function of the " starter " is to act as an inoculant carrying a vigorous micro-flora for decomposition. The addition of an inoculum, such as actively fermenting compost (used by Dr. Fowler in his Activated Compost method) dung, night soil or sewage, shortens the time of composting. (3) The maintenance of an optimum moisture level in the compost heap—usually 50% of the wet heap—with the reaction at the natural or slightly alkaline range is insisted on. In the Hot Fermentation method the loss of moisture by evaporation is prevented by covering the heap with earth and mud paste (4) A proper physical condition or body in the compost heap is necessary to start with. Woody materials such as cotton stalks may be broken down under the feet of cattle or under the wheels of carts (5) The rise of temperature in the compost heap destroys weed seeds, fly maggots, worms and pathogenic organisms. The points of difference between the various methods of composting at present in use are the following:— (1) The majority of methods are " aerobic "